PMI®

It (Implementing Deep Space Flight Projects) IS Risky Business

Dr. James R Rose
Jet Propulsion Laboratory

September 13-14, 2002

PMI® Risk Management Specific Interest Group

Outline

- Background
- Deep Space Exploration Today
- Management Culture Changes
- Risk Management as a Process
- Application Experiences
- Where are we going?

Risk Management in the Deep Space Project Environment

- Two kinds of projects
  - First of a Kind
  - Significant inheritance
- Application of a priori data
  - Minimal at best
  - "Lessons Learned"/ Expert Judgment approach

Yesterday's Approach

- Few Missions
  - JPL had one or two missions in implementation
  - Ames with Pioneer
- Management Approach
  - Primarily in-house
  - Experienced Project Teams – learn on the job
  - Significant early failures on Ranger led to standardization of implementation process

Yesterday's Approach (Cont'd)

- Approach to Mission Success
  - Approach used on the previous mission the starting point for the next mission
  - Rigorous/ expensive assurance process
- Technical Approach
  - Conservative application of new design/ technology
  - Design "rules", systems engineering processes
  - Engineers mentored on the job in the JPL process

Yesterday's Approach (Cont'd)

- Mission Operations Implementation
  - Short missions (Mars, Venus, Lunar)
  - Implementation Team provided strong technical operations team component
  - Deep Space Network committed to a few mission
    - Incremental performance improvements
    - Managed by JPL
  - Mission Operations complex managed by JPL
  - Conservative use of flight autonomy – fail safe approach
  - Rudimentary (although high-tech at the time) software content

Then What?

- Viking, Voyager, Galileo, Cassini
- Push to Relax Government Dictation to Industry of How to do Business
- Better, Faster, Cheaper
- Many Small, Contained Missions
- ISO/ NASA NPG 7120.5

Then What (cont'd)?

- Viking, Voyager, Galileo, Cassini
  - Complex technology, demanding designs
  - Stretched the inheritance mode of implementation
  - Result – **very successful**, but:
    - applying the traditional conservative (risk-averse) approaches was very expensive
    - Programmatic Environment did not support billion dollar endeavors
  - Recognized the need to share more of the work with industry
    - Magellan, Mars Observer
  - Industry did things in different ways
  - New risk areas

Then What (cont'd)?

- Push to Relax Government Dictation to Industry of How to do Business
  - Standards are too expensive – apply industry "best practices"
  - Streamline the acquisition/ oversight process
  - Result:
    - Some inefficiencies and cultural learning experiences
    - Some mistakes – some leading to mission failure
  - Contemporary with Challenger
  - NASA inserts itself more intimately in the JPL implementation process
    - Risk Management as a defined process and specific activity is introduced.

Then What (cont'd)?

- Better, Faster, Cheaper
  - Small teams, Skunk-works approaches
  - Short Development Period
  - Limited Oversight – trust me
  - Capitalize on excess from last big missions
  - Complements the previous relaxing of standards
  - Be more risk-tolerant

Then What (cont'd)?

- Many Small, Contained Missions
  - NASA Planetary Exploration Budget did not decline
  - Put eggs in many more baskets
  - Opened the process to non-JPL managed projects
  - Introduced the PI (Principal Investigator)- led projects
  - Results:
    - Some spectacular success
    - Depletion of expertise
    - Ate some of the seed corn
    - Some failure – and realization that we really didn't accept failure after all

Then What (cont'd)?

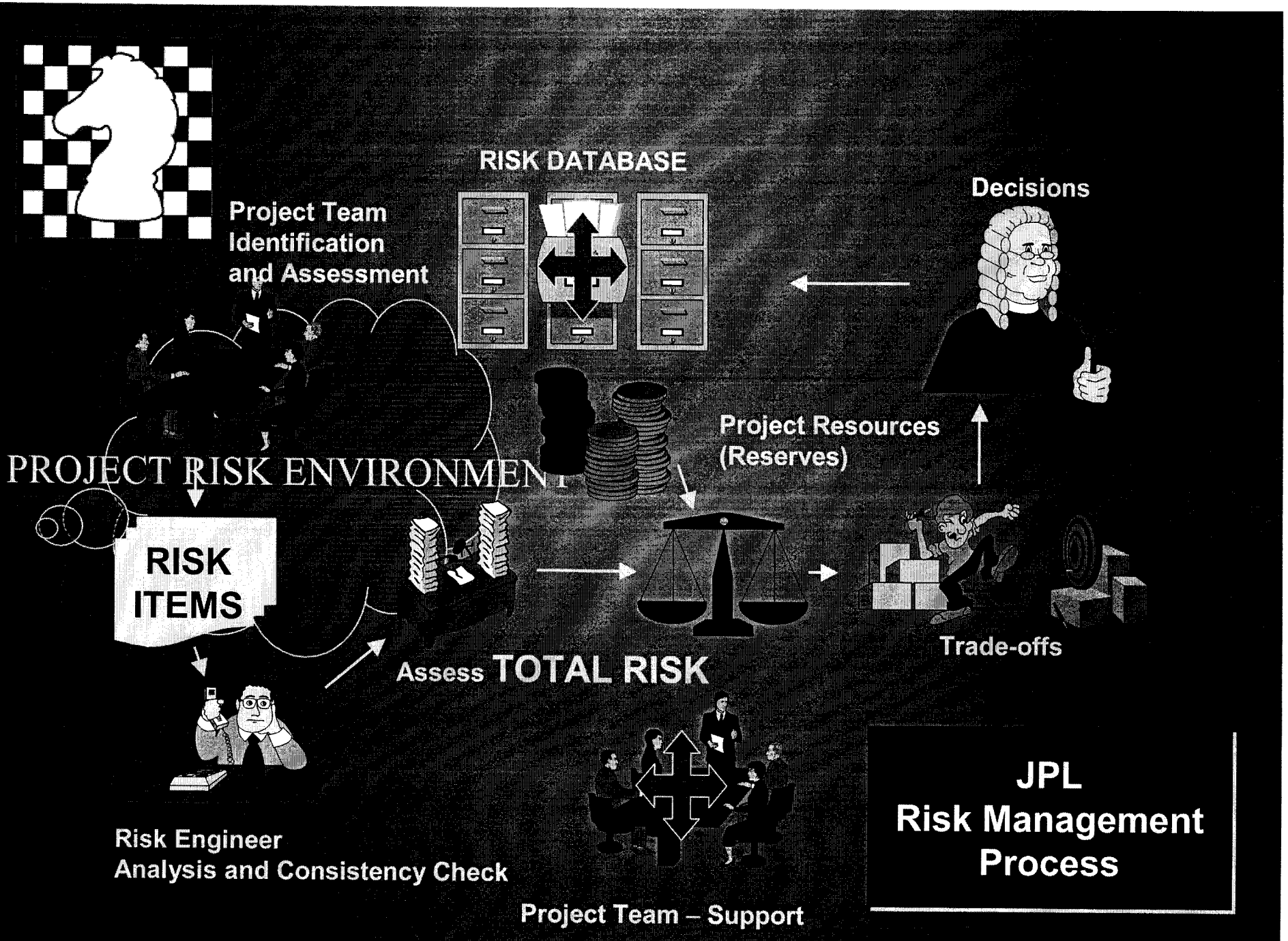
- ISO/ NASA NPG 7120.5
  - Document your process and demonstrate that you follow it.
  - Resulted in more documentation before, and more formal processes
  - This was consistent with realizing that training was needed to replace the experience-base of the previous era
  - Risk Management process borrowed from the Nuclear, Environmental industries and adapted to the one-of-a-kind nature for Space Flight projects
  - Results:
    - Process implemented on all flight projects
    - Risk lists sprang up quickly
    - Risk Management Plans required and produced
    - Risk used as an independent assessment metric

Where Are We Today?

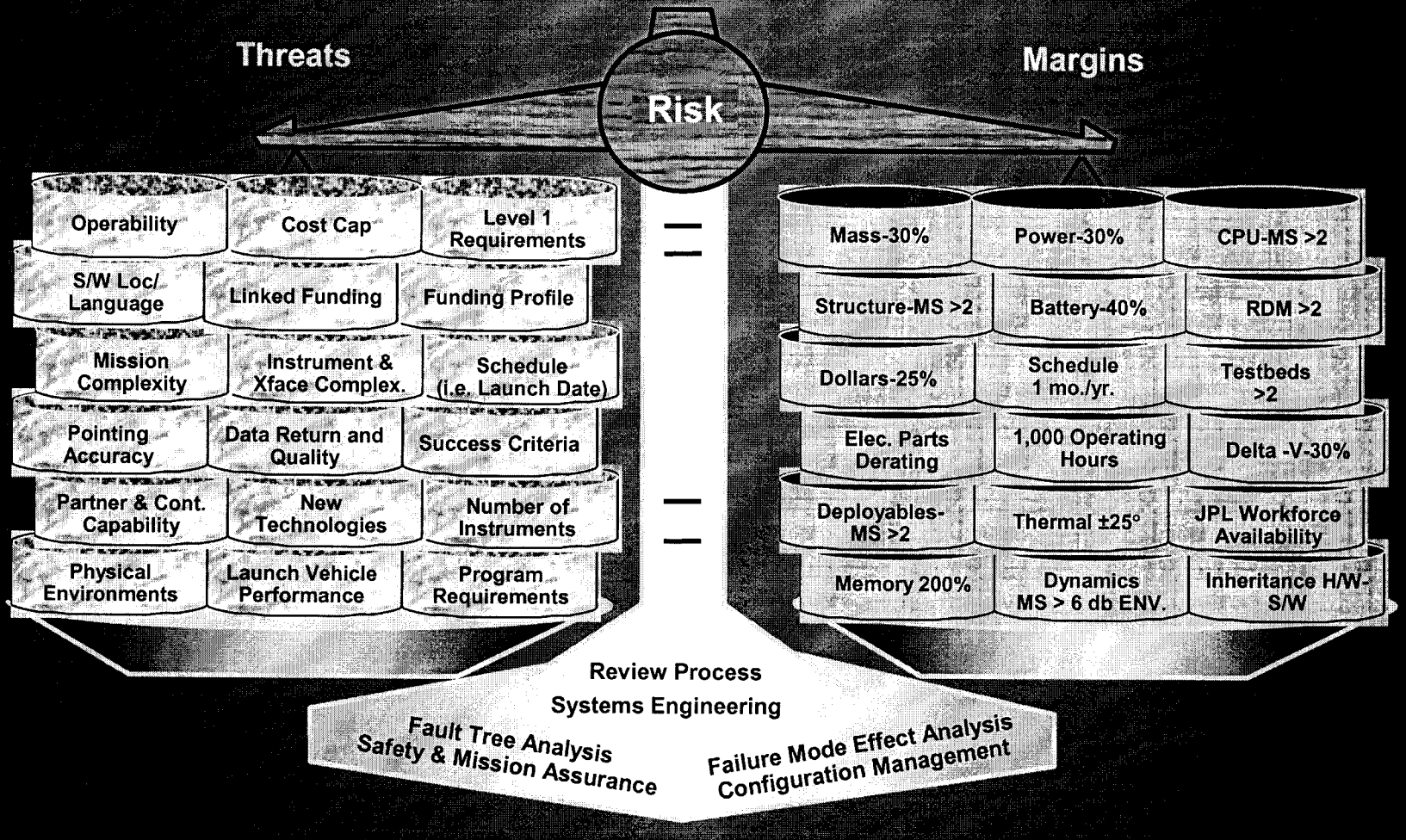
- Projects
  - Some 20 - 25 active projects in Implementation
  - Projects range in size from $25M to $750M
  - Extensive training and mentoring to provide for lack of project management experience
  - Documenting the way wee do business in a process structure
  - Establishing practices, principles, and rules to allow insight into activities
  - Independent Technical and Management Reviews provide management insight and encourage management involvement

Where Are We Today? (cont'd)

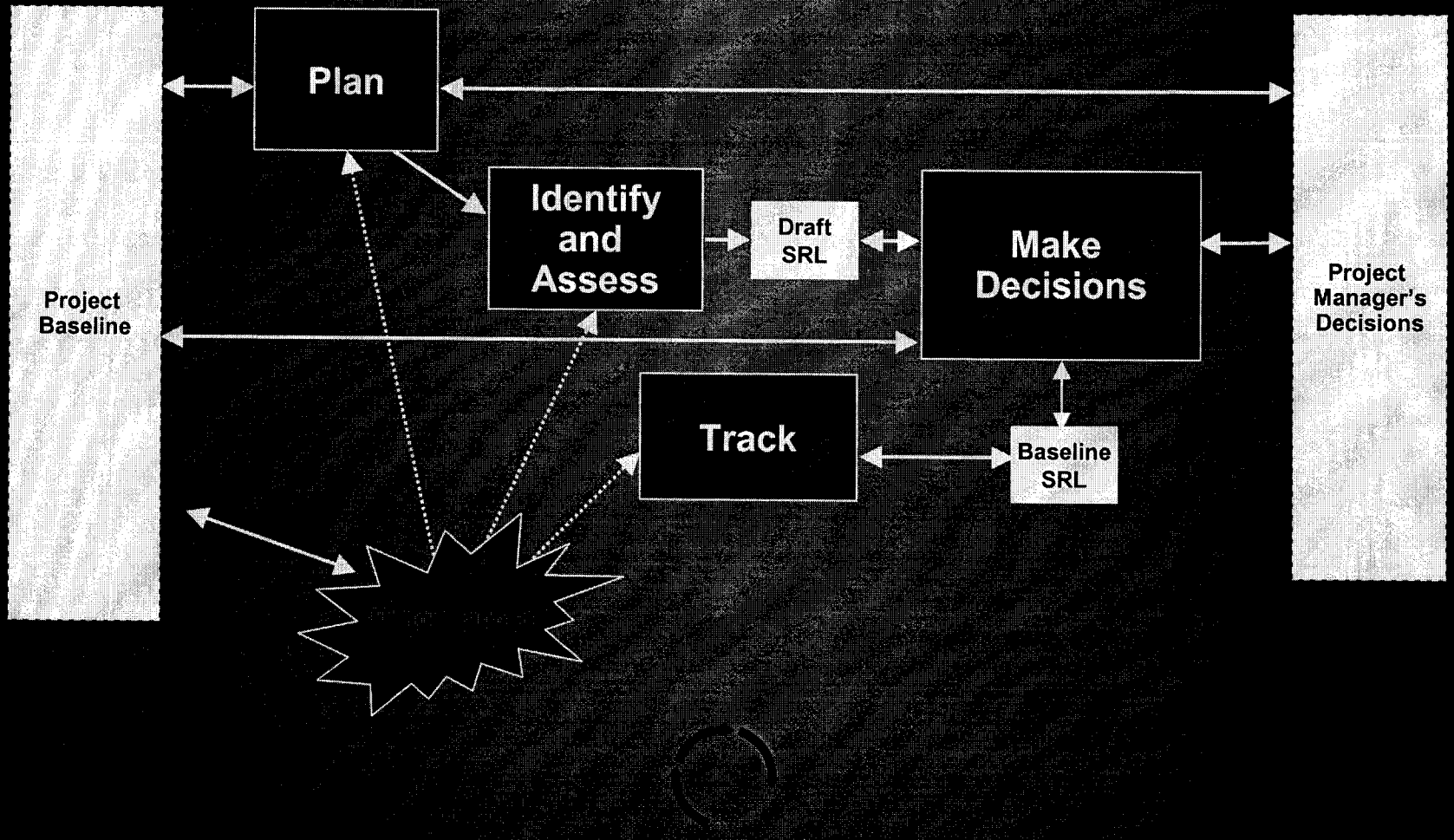
- Programs
  - Program Management delegated to Centers
  - New Millennium, Mars, Navigator programs have Risk drivers – need a Risk Management process unique to program characteristics
- Institution
  - Desire to standardize process
  - Improving Cost Estimation process with Risk-related considerations


RISK DATABASE
Project Team
Identification
and Assessment
Decisions
Project Resources
(Reserves)
PROJECT RISK ENVIRONMENT
RISK
ITEMS
Trade-offs
Assess TOTAL RISK
Risk Engineer
Analysis and Consistency Check
Project Team – Support
JPL
Risk Management
Process

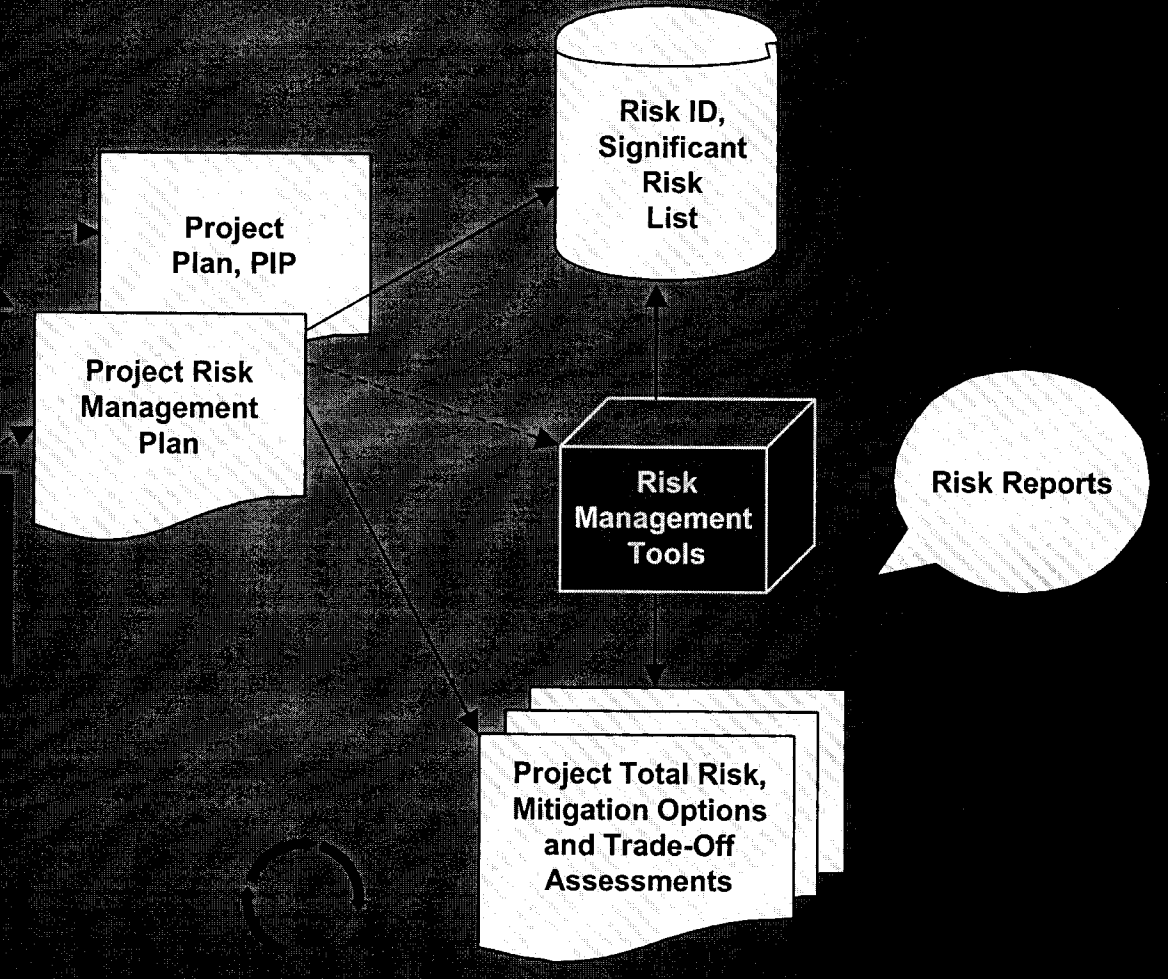
Achieving Balanced Risk



RM Process Flow



Key Process Tools and Resources



- Procedure:
  (Risk Management Handbook for JPL Projects)
- RM Plan Template

JPL Processes/ OSMS Support

Project Implementation

Identifying Risks

Pre-Project Proposal
- Technical Margins
- Project Risk Drivers
- Cost & Schedule Uncertainty Assessment

Project Planning
- Lessons Learned, etc.
- Design Principles
- WBS Analysis (work included, omitted, etc.)
- Schedule Analysis
- Reserves Analysis
- Design Baseline Risk Analysis (Trade-off studies, System FMEA, FTA, PRA, DDP, etc.)

Project Implementation
- Design Reviews
- Monthly Status Assessments
- Development tests
- Changes in metrics
- Risk reassessments and detailed analyses (Component FTAs, FMECAs, I/F FMEAs, etc.)
- Maturing design, mfg, ass'y, test, etc.
- Problem resolution
- Things happen

TIME

Expert Judgment
- Risk Owners
- Risk Manager
- Project Manager

Risk Identification

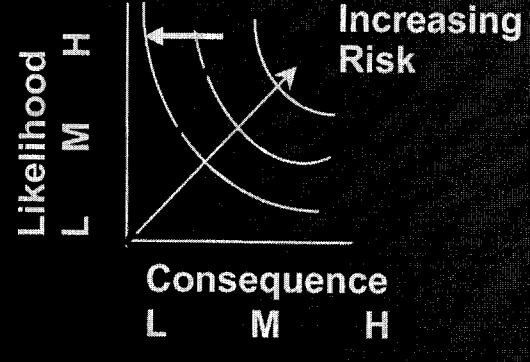
Qualitative Approach to RM

Assessing Risks

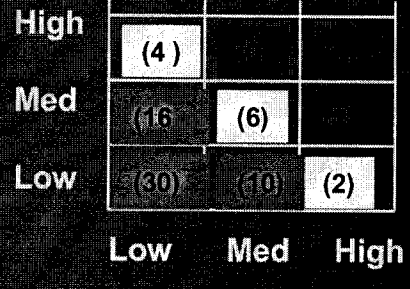
Risk Item "i"

Likelihood:	Relative scale, e.g., Low, medium, high (from "no way" to "for sure")
Consequence:	Relative scale, e.g., Low, medium, high (from "no sweat" to "total disaster")
Risk Measure:	[redacted] on risk graph
Mitigation Effect:	"Mitigation Vector" on risk graph

Risk item "i"



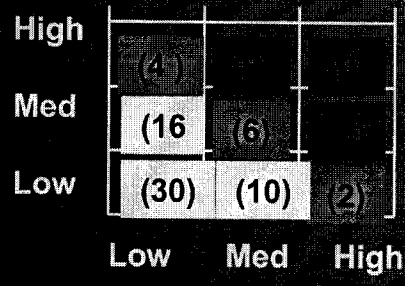
Project Total Risk Position:



Qualitative Approach to RM
Making Decisions

- Identify total risks
- Examine effectivity of mitigation options (example mitigation checklists in back-up)
- Implement - proactive risk reduction

Project Total Risk Position:



- Impact to reserves
  - –>75% (?) from Primary Risks
  - –>But 15% from yellow risks can kill you
  - –>Cost of **mitigations** weighed against risk cost reductions
  - –>**Proactive use of reserves where mitigation is risk-effective**

Quantitative Approach to RM

Assessing Risks

Risk Item "i"

Likelihood: Measured from 0 to 1 (from "no way" to "for sure") - p_i

Consequence: Measured as a percentage of impact on Project resource element k - I_{ik}

Project Risk Resource Elements:

- Projects identify most sensitive
- Typical resources at risk:
  - (1) Implementation Risk ($, mass, power, memory)
  - (2) Mission Risk (impact on mission success)

Risk Measure: Product of likelihood and consequence: $p_i x I_{ik}$

For each consequence category (k), probabilistic sum of $p_i x I_{ik}$ over (i)

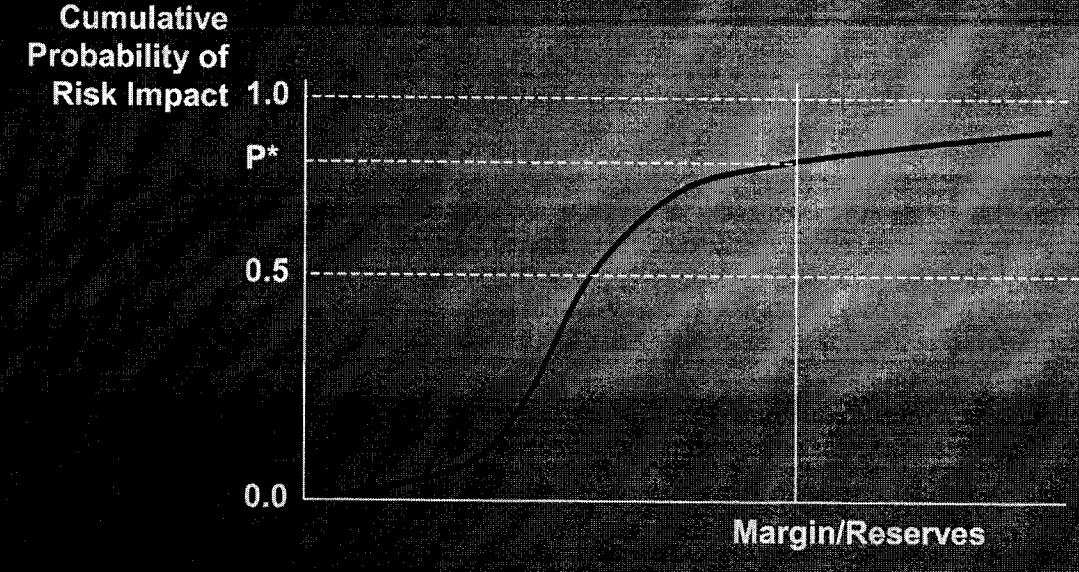
(For most practical cases, can assume risks and consequences are independent, and therefore

=[sum over all i]$p_i x I_{ik}$)

Quantitative Approach to RM

Making Decisions

Aggregating Risk



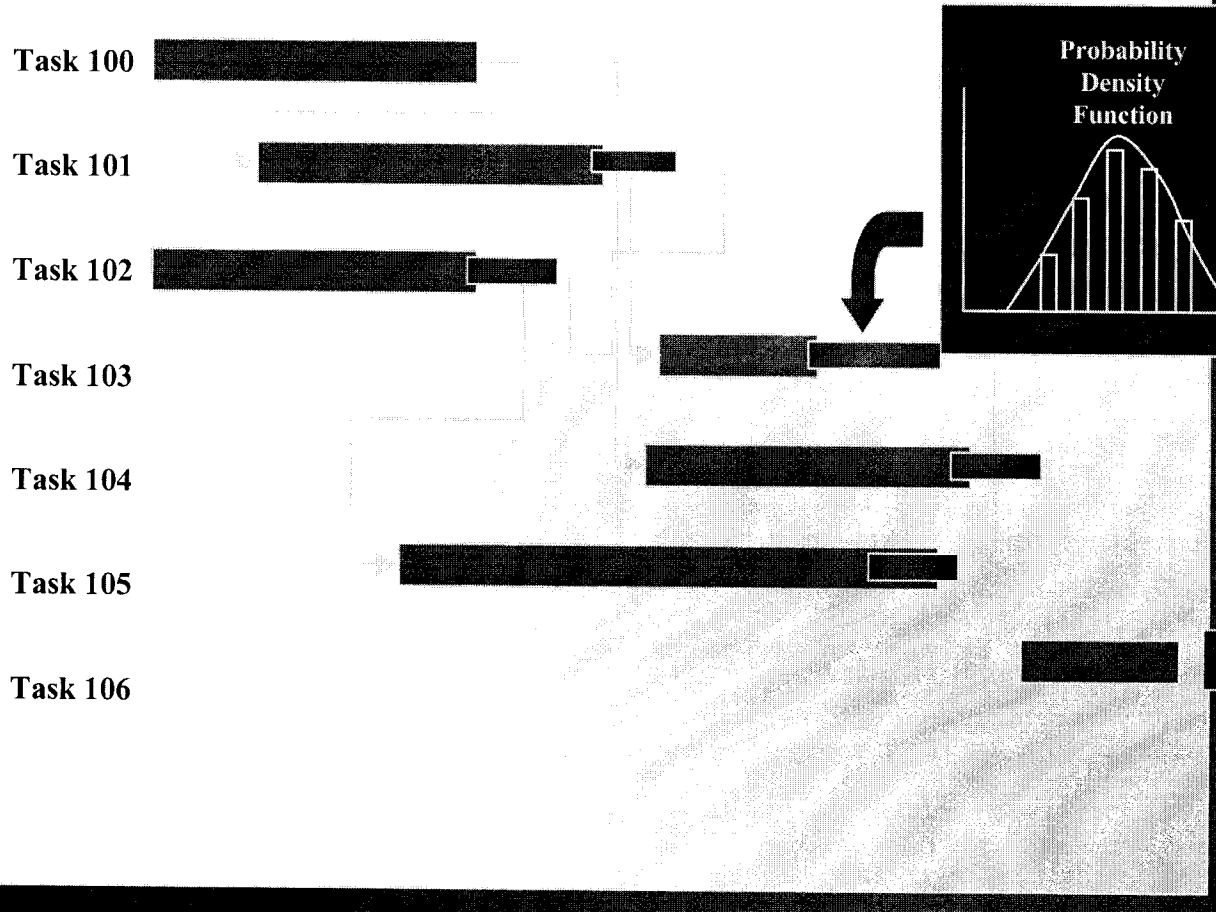
Aggregate of the Risk Items – Total Prof

*"P" is the likelihood that that particular resource will be sufficient to handle the known risks to the Project

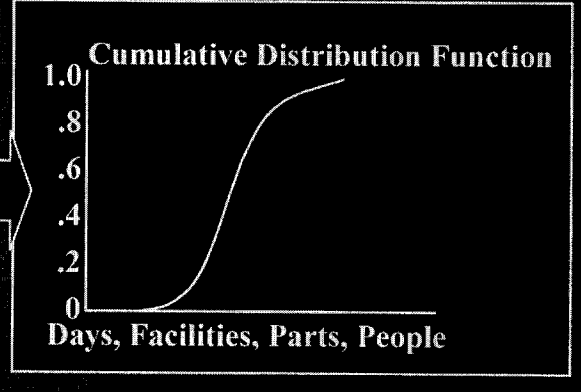
Aggregating Risk
Schedule Risk Analysis

Genesis Experience - Analysis provided by Futron Corporation

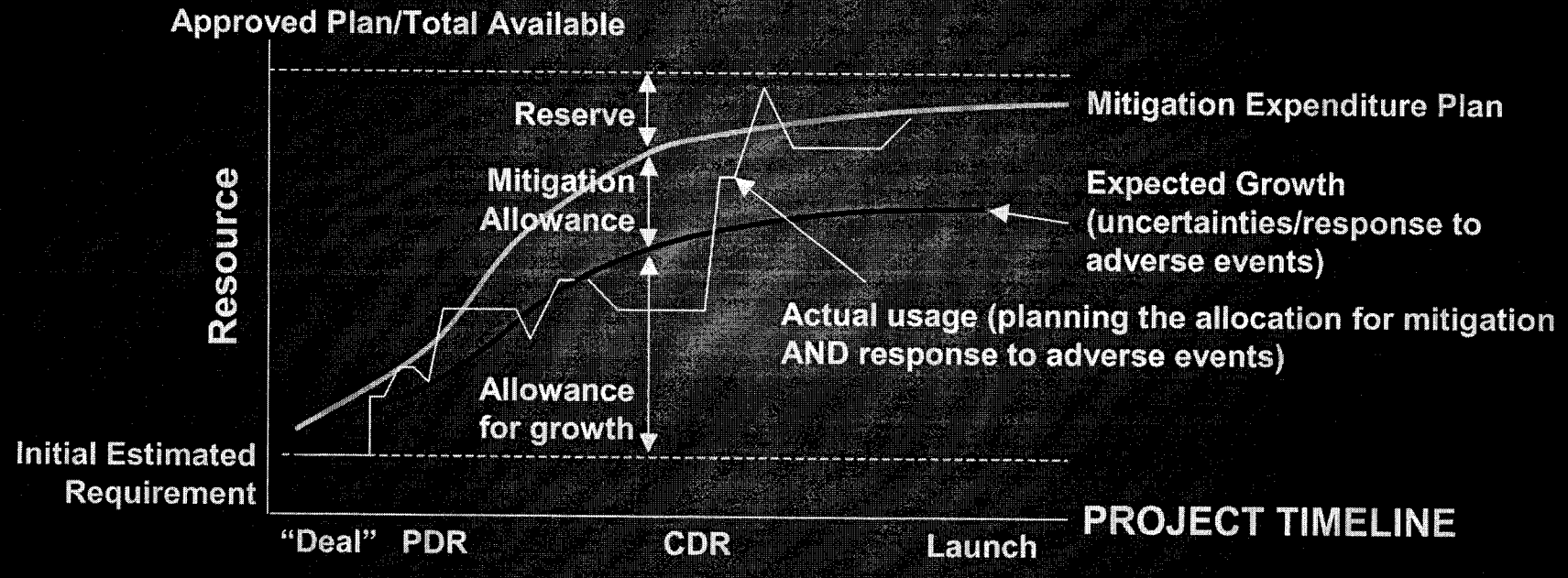
WBS Integrated resource-loaded Schedule Network



Monte Carlo Sim. Tool



Technical Risk Metrics
An Example



- Examples: mass, power (in all forms), memory, bandwidth, throughput, pointing budget, noise, etc.

Identifying Risks

Pre-Project Proposal
- Technical Margins
- Project Risk Drivers
- Cost & Schedule Uncertainty Assessment

Project Planning
- Lessons Learned, etc.
- Design Principles
- WBS Analysis (work included, omitted, etc.)
- Schedule Analysis
- Reserves Analysis
- Design Baseline Risk Analysis (Trade-off studies, System FMEA, FTA, PRA, DDP, etc.)

Project Implementation
- Design Reviews
- Monthly Status Assessments
- Development tests
- Changes in metrics
- Risk reassessments and detailed analyses (Component FTAs, FMECAs, I/F FMEAs, etc.)
- Maturing design, mfg, ass'y, test, etc.
- Problem resolution
- Things happen

TIME

Expert Judgment
- Risk Owners
- Risk Manager
- Project Manager

Risk Identification

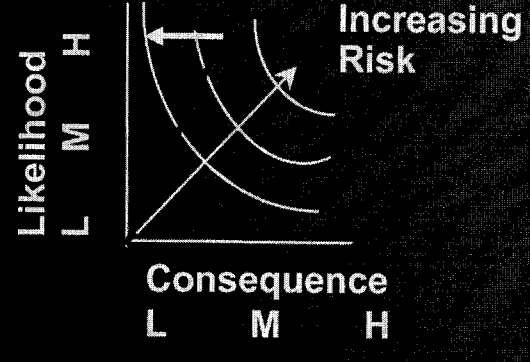
Qualitative Approach to RM

Assessing Risks

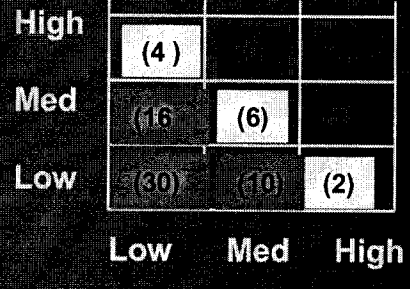
Risk Item "i"

Likelihood:	Relative scale, e.g., Low, medium, high (from "no way" to "for sure")
Consequence:	Relative scale, e.g., Low, medium, high (from "no sweat" to "total disaster")
Risk Measure:	[redacted] on risk graph
Mitigation Effect:	"Mitigation Vector" on risk graph

Risk item "i"



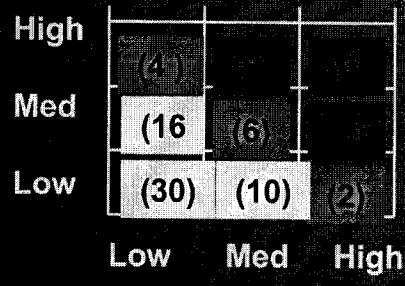
Project Total Risk Position:



Qualitative Approach to RM
Making Decisions

- Identify total risks
- Examine effectivity of mitigation options (example mitigation checklists in back-up)
- Implement - proactive risk reduction

Project Total Risk Position:



- Impact to reserves
  - –>75% (?) from Primary Risks
  - –>But 15% from yellow risks can kill you
  - –>Cost of **mitigations** weighed against risk cost reductions
  - –>**Proactive use of reserves where mitigation is risk-effective**

Quantitative Approach to RM

Assessing Risks

Risk Item "i"

Likelihood: Measured from 0 to 1 (from "no way" to "for sure") - p_i

Consequence: Measured as a percentage of impact on Project resource element k - I_{ik}

Project Risk Resource Elements:

- Projects identify most sensitive
- Typical resources at risk:
  - (1) Implementation Risk ($, mass, power, memory)
  - (2) Mission Risk (impact on mission success)

Risk Measure: Product of likelihood and consequence: $p_i x I_{ik}$

For each consequence category (k), probabilistic sum of $p_i x I_{ik}$ over (i)

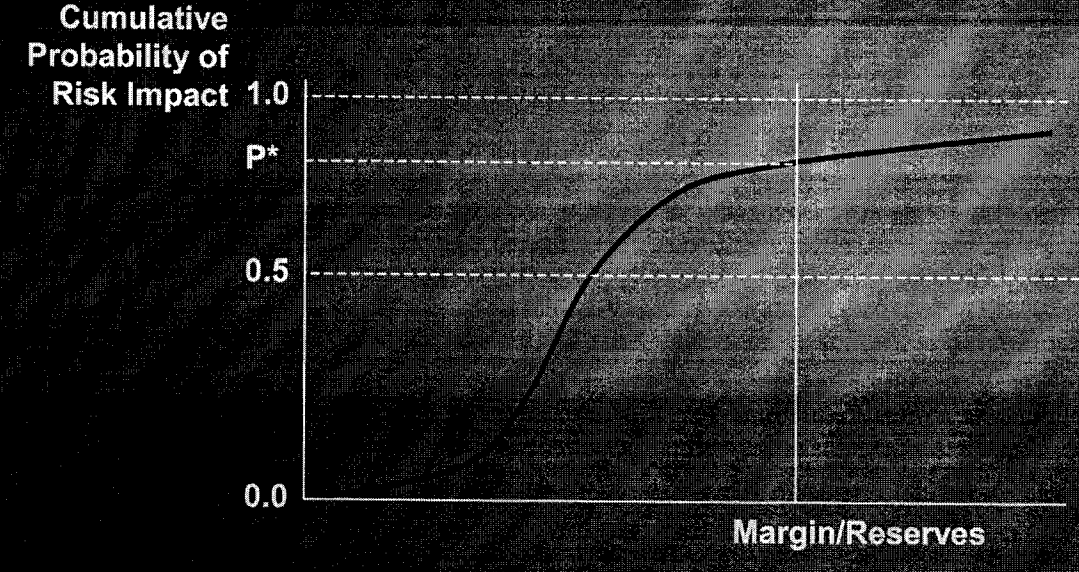
(For most practical cases, can assume risks and consequences are independent, and therefore

=[sum over all i]$p_i x I_{ik}$)

Quantitative Approach to RM

Making Decisions

Aggregating Risk



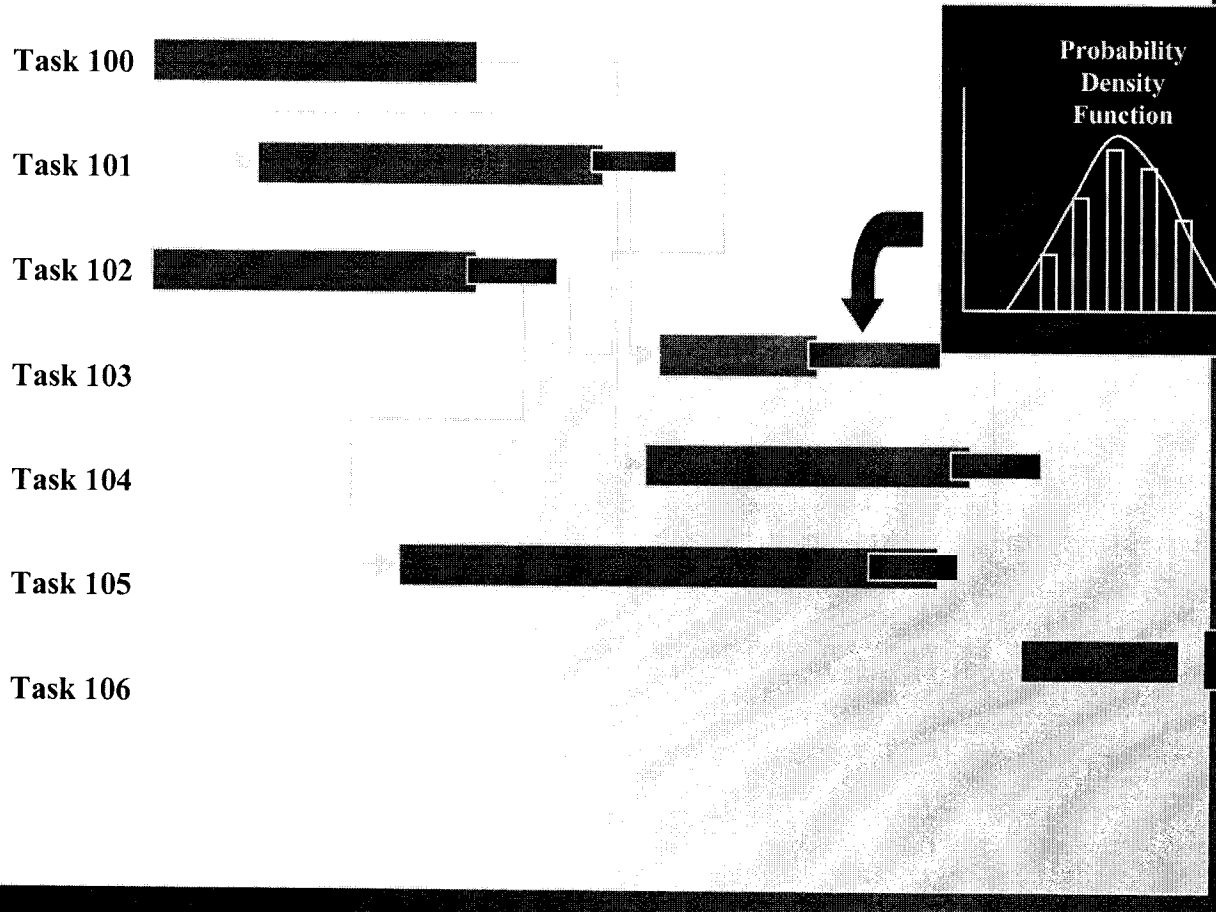
Aggregate of the Risk Items – Total Prof

*"P" is the likelihood that that particular resource will be sufficient to handle the known risks to the Project

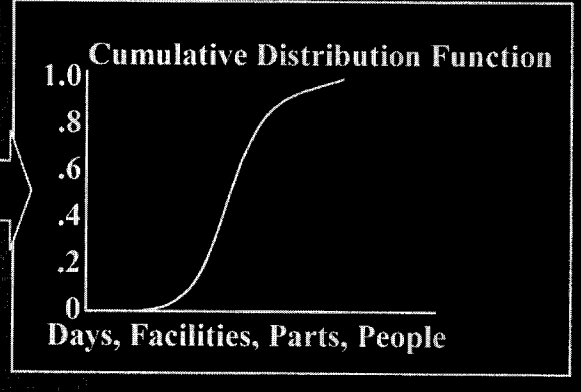
Aggregating Risk
Schedule Risk Analysis

Genesis Experience - Analysis provided by Futron Corporation

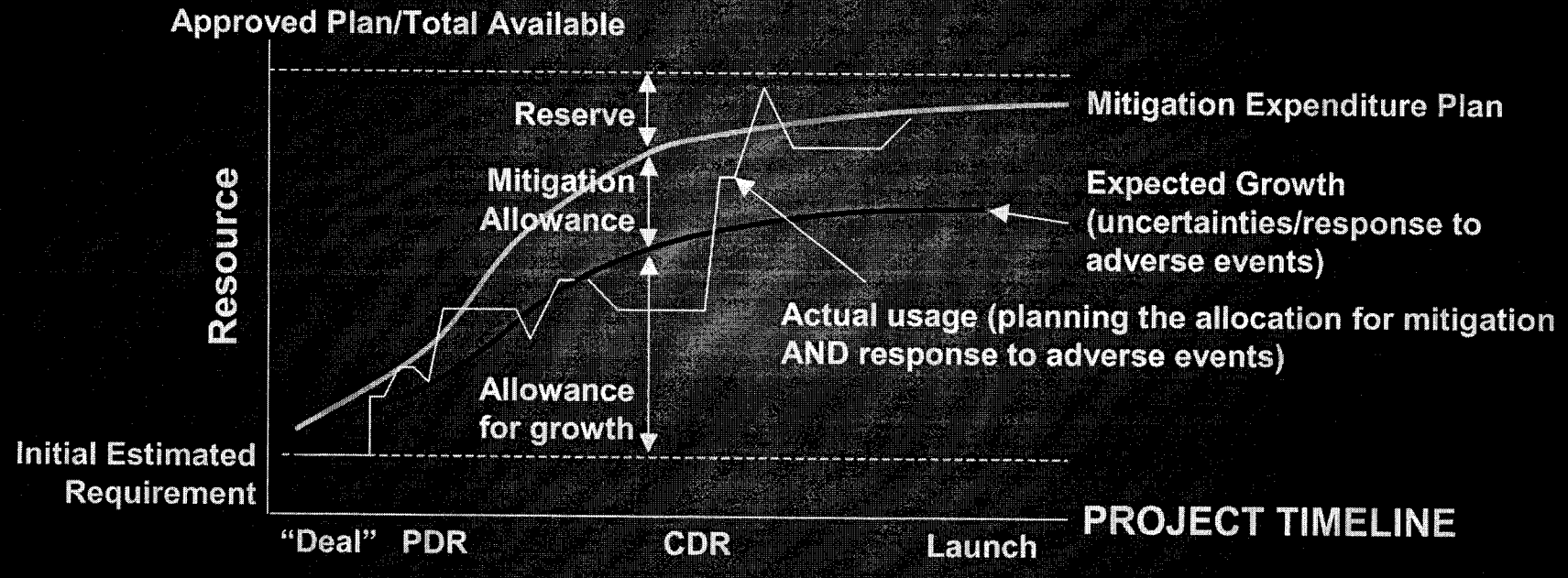
WBS Integrated resource-loaded Schedule Network



Monte Carlo Sim. Tool



Technical Risk Metrics
An Example



- Examples: mass, power (in all forms), memory, bandwidth, throughput, pointing budget, noise, etc.

Where Are We Going?

- Programmatic
  - Integrating Project Resource and Risk management Processes through common data and process measurements (e.g., lien management)
  - Developing methodology to effectively apply statistical risk assessment tools (PRA, etc.)
- Institution
  - Developing standardized cross-project risk assessment criteria – allow senior management to better understand project risk positions
  - Integrating risk consideration into all aspects of managing our space flight activities

Conclusions

- Projects are Accepting Risk Management
  - Gaining confidence that RM will help
  - Most of the really effective methods come out of the projects' unique implementation approaches
- Training is Important
  - Training needs to be hands-on, interactive
- Experts are Good
  - But the project personnel must own the process

Acknowledgment

This Research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration